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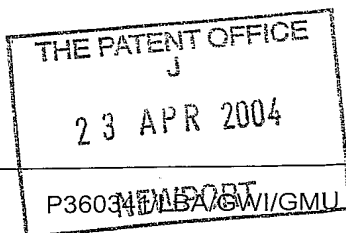


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1. Your reference

2. Patent application number

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23 APR 2004

0409065.0

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Lloyd (Scotland) Limited
152 Bath Street
Glasgow
G2 4TB

Patents ADP number (*if you know it*)

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

8776932001

4. Title of the invention

Body Protecting Device

5. Name of your agent (*if you have one*)

Murgitroyd & Company

"Address for service" in the United Kingdom to which all correspondence should be sent (*including the postcode*)

Scotland House
165-169 Scotland Street
Glasgow
G5 8PL

Patents ADP number (*if you know it*)

1198015

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (*if you know it*) the or each application number

Country

Priority application number
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Date of filing
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (*Answer 'Yes' if:*

Yes

- a) any applicant named in part 3 is not an inventor, or
 - b) there is an inventor who is not named as an applicant, or
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Description 13

Claim(s) 4

Abstract 1

Drawing(s) 4

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Priority documents -

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Statement of inventorship and right to grant of a patent (Patents Form 7/77) -

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11. I/We request the grant of a patent on the basis of this application.

Signature *Murgitroyd & Company* Date 22 April 2004
Murgitroyd & Company

12. Name and daytime telephone number of person to contact in the United Kingdom GLEN WILSON 0141 307 8400

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1 Body Protecting Device

2

3 The present invention relates to body protecting
4 devices. In particular, but not exclusively, the
5 invention relates to the energy absorbing materials
6 used in devices having a relatively large curvature
7 such as safety helmets, elbow pads, knee pads,
8 shoulder pads and the like, and methods of forming
9 such materials.

10

11 Many body protecting devices have a large curvature,
12 κ , which is defined as the inverse of the radius of
13 curvature, ρ , for the device. The device, such as a
14 safety helmet, may require a permanently curved
15 shape. Other devices, such as pads for elbows,
16 knees and shoulders, may have to be sufficiently
17 flexible to elastically adopt such a curved shape in
18 response to movements of the body. Suitable
19 materials and forming methods must be used for these
20 devices.

21

1 Crash helmets conventionally comprise a
2 substantially spheroidal outer skin of tough
3 plastics material and an inner skin of resilient
4 material such as a hard foam. The rigid outer skin
5 transmits an impact load more evenly to the inner
6 skin which absorbs the energy imparted by the impact
7 load. The helmets are formed in a female mould, or
8 around a male mould, and the materials must undergo
9 significant curvature to form the spheroidal shape.
10 Also, the outer and inner skins must be inserted
11 separately to the mould. Otherwise, during bending,
12 the bond between the two materials would prevent the
13 necessary slippage of the outer skin (which is
14 stretched) relative to the inner skin (which is
15 compressed), or else would produce high planar
16 stresses at the internal and external surfaces.

17
18 It may be desirable to decrease the total mass of
19 the helmet. Also, the methods of forming the
20 helmets, which typically involve hand lay-up, tend
21 to be complex and expensive. It would be
22 advantageous to be able to insert the inner and
23 outer skin as a one-piece material within the mould.

24
25 Axially loaded columns of various cross sectional
26 shapes have been used for some time to improve the
27 structural crashworthiness of vehicles, roadside
28 furniture and the like. Metal columns exhibit a
29 multiple buckling and folding failure mode which is
30 effective in absorbing impact energy. Plastic and
31 composite columns have a number of failure modes but

1 all of the modes typically involve progressive
2 crushing of one end of the column.

3
4 The performance and failure mode of plastic and
5 composite columns depends on a complex interaction
6 of a number of different parameters including the
7 material used, the geometry (shape and thickness),
8 fibre alignment in composites, the use of triggers,
9 and the loading conditions. However, a careful
10 selection of these parameters can result in a safety
11 device which outperforms the metal equivalent.

12
13 Regardless of the material used, arrays of columns
14 arranged parallel to the load have generally been
15 found to increase energy absorbing performance and
16 improve the stability of the safety device. Columns
17 tend to produce a relatively constant level of
18 energy absorption as the column is progressively
19 buckled or crushed. Axially loaded cones have been
20 found to produce a more linearly increasing rate of
21 energy absorption which can often be more desirable
22 in crash situations.

23
24 Sandwich panels, consisting of two tough outer skins
25 separated by a core material having a lower
26 stiffness, have been used in many applications such
27 as building components and structural panels for
28 road vehicles and aircraft. A popular core consists
29 of a honeycomb structure, that is an array of
30 longitudinal members, each member having a hexagonal
31 cross-section. The axis of each longitudinal member
32 is normal to the plane of the inner and outer skins

1 and each end of each longitudinal member is
2 typically bonded to the respective skin. Therefore,
3 the honeycomb structure represents an array of
4 columns arranged parallel to a load which impacts
5 the plane of one of the outer skins.

6
7 WO 94/00031 discloses a safety helmet which includes
8 a honeycomb sandwich structure. Generally, a hand
9 lay-up method is used. EP 0881064 discloses a
10 protective element which also has a honeycomb
11 sandwich structure. The document states that the
12 element may be incorporated within a wide range of
13 protective clothing which includes helmets.

14
15 Honeycomb structures are suitable for applications
16 involving flat panels or structures with only a
17 relatively small curvature. However, problems arise
18 when the material is used in items having a large
19 curvature.

20
21 Each hexagonal cell of the honeycomb structure has a
22 rotation symmetry angle of $n \cdot 60^\circ$. The cell
23 therefore does not have rotation symmetry about an
24 angle of 90° . The cell is therefore not
25 orthotropic, that is it has a different response to
26 a load applied at a first angle than to a load
27 applied at a second angle which is applied at 90°
28 from the first angle. When forming a helmet, the
29 material is bent around a mould about two orthogonal
30 axis to form the spheroidal shape. Therefore, a
31 hexagonal structure can create difficulties when
32 trying to achieve the curvature desired.

1
2 Furthermore, a hexagonal structure is by nature
3 anticlastic, in that a positive curvature about an
4 axis results in a negative curvature about an
5 orthogonal axis (the shape of a saddle illustrates
6 this phenomenon). This again leads to difficulties
7 in the forming process.

8
9 Furthermore, there are disadvantages in using a
10 honeycomb structure for devices such as pads which
11 must elastically deform to a large curvature. These
12 disadvantages include the relatively rigid nature of
13 the structure. A hexagonal element can be
14 considered to be six flat plates, each of which are
15 rigidly fixed at each longitudinal edge. It is
16 known theoretically and empirically that such
17 elements, and structures produced from these
18 elements are relatively inflexible. A pad produced
19 from such a material can tend to feel stiff and less
20 comfortable. It is desirable that comfort be
21 improved without any sacrifice in the energy
22 absorbing capability of the device.

23
24 According to a first aspect of the present invention
25 there is provided a body protecting device
26 comprising:

27 a first material having an array of energy
28 absorbing cells, wherein each cell comprises a tube.

29
30 The term "tube" is used to denote a hollow
31 cylindrical or conical structure, preferably a
32 circular cylindrical or circular conical structure.

1 The tubular array results in a material which is
2 substantially isotropic and substantially non-
3 anticlastic.

4

5 Preferably the body protecting device comprises a
6 safety helmet. Alternatively, the body protecting
7 device comprises a safety pad.

8

9 Preferably each tube has a diameter of between 2 and
10 8 mm.

11

12 Preferably the first material has, or can deform to,
13 a large curvature.

14

15 Preferably the first material comprises
16 polycarbonate, polypropylene, polyetherimide,
17 polyethersulphone or polyphenylsulphone. Preferably
18 the material comprises Tubus HoneycombsTM.

19

20 According to a second aspect of the present
21 invention there is provided a liner for a body
22 protecting device, the liner comprising:

23 a first material having an array of energy
24 absorbing cells, wherein each cell comprises a tube.

25

26 Preferably the body protecting device comprises a
27 safety helmet. Alternatively, the body protecting
28 device comprises a safety pad.

29

30 According to a third aspect of the present
31 invention, there is provided a body protecting
32 device comprising:

1 a first material bonded to a second material
2 using an adhesive, wherein the adhesive has a melt
3 temperature which is lower than the melt temperature
4 of the first and second material.

5
6 Preferably the body protecting device comprises a
7 safety helmet. Alternatively, the body protecting
8 device comprises a safety pad.

9
10 Preferably the first and second materials are in a
11 softened state at the melt temperature of the
12 adhesive. This allows thermoforming of the helmet
13 at the melt temperature of the adhesive, as the
14 melted bond allows relative movement between the
15 first and second materials.

16
17 Preferably the first material is one of a
18 polycarbonate, polypropylene, polyetherimide,
19 polyethersulphone or polyphenylsulphone material.

20
21 Preferably the second material is a plastics
22 material, such as polyetherimide. Preferably the
23 second material is a fibre reinforced plastics
24 material. Preferably the fibres are made from glass
25 or carbon.

26
27 Preferably the adhesive is a thermoplastic.
28 Preferably the adhesive is a polyester based
29 material.

30

1 Preferably the melt temperature of the adhesive is
2 less than 180°C. Preferably the melt temperature of
3 the adhesive is between 120°C and 140°C.

4

5 Preferably the body protecting device is heated
6 during forming to between 155°C and 160°C.

7

8 Preferably the body protecting device further
9 comprises a third material and the first material
10 interposes the second and third materials.

11 Preferably the first material is bonded to the third
12 material using the adhesive.

13

14 Preferably the first material has an array of energy
15 absorbing cells, each cell comprising a tube.

16

17 According to a fourth aspect of the present
18 invention there is provided a method of forming a
19 body protecting device comprising:

20 bonding a first material to a second material
21 using an adhesive, wherein the adhesive has a melt
22 temperature which is lower than the melt temperature
23 of the first and second material.

24

25 Preferably the body protecting device comprises a
26 safety helmet. Alternatively, the body protecting
27 device comprises a safety pad.

28

29 Preferably the method includes selecting first and
30 second materials which are in a softened state at
31 the melt temperature of the first material.

32

1 Preferably the method includes heating the body
2 protecting device during forming to between 155°C
3 and 160°C.

4

5 Preferably the method includes bonding the first
6 material to a third material using the adhesive.

7

8 Preferably the first material has an array of energy
9 absorbing cells, each cell comprising a tube.

10

11 An embodiment of the present invention will now be
12 described, by way of example only, with reference to
13 the accompanying drawings, in which:

14

15 Fig. 1 is a perspective view of a safety helmet in
16 accordance with the present invention;

17

18 Fig. 2 is a side view of the sandwich panel used to
19 form the helmet of Fig. 1;

20

21 Fig. 3 is a side view of the sandwich panel of Fig.
22 2 in a curved state;

23

24 Fig. 4 is a plan view of a known arrangement of
25 cells used for the core of a sandwich panel.

26

27 Fig. 5 is a plan view of a tubular array of cells
28 used in the sandwich panel of Fig. 2;

29

30 Fig. 6 is a sectional side view of the tubular array
31 of Fig. 5 in a curved state;

32

1 Figs. 7a, 7b and 7c are exaggerated plan views of
2 positions of the tubular array of Fig. 6 which are
3 compressed, neutral and extended respectively;
4

5 Fig. 8 is a side view of the heating process used
6 for the sandwich panel of Fig. 2;
7

8 Fig. 9 is a cross sectional side view of a mould
9 used in conjunction with the sandwich panel of Fig.
10 2; and
11

12 Fig. 10 is the sandwich panel of Fig. 2 in a moulded
13 state.
14

15 Referring to Figs. 1 to 3, there is shown a body
16 protecting device in the form of a safety helmet 10.
17 The helmet 10 is formed using a panel 12 which
18 comprises a first material or core 20 which is
19 sandwiched by a second material or outer skin 30 and
20 a third material or inner skin 50. Each of the
21 outer 30 and inner 50 skins are bonded to the core
22 using an adhesive 40.
23

24 Fig. 3 shows the sandwich panel 12 in a curved
25 state. In such a state, the material varies
26 linearly from a state of zero stress (in respect of
27 the major planes of the panel 12) at the neutral
28 axis 14 to a state of maximum tensile stress at the
29 exterior face of the outer skin 30 and a state of
30 maximum compressive stress at the interior surface
31 of the inner skin 50. These tensile and compressive
32 stresses cause tensile and compressive strains

1 respectively. Therefore, there is slippage between
2 the outer skin 30 and the core 20 and the inner skin
3 50 and the core 20 unless this slippage is prevented
4 by the adhesive 40.

5
6 A known core structure is a honeycomb or hexagonal
7 arrangement which is shown in Fig. 4. Each
8 hexagonal cell 60 has a rotation symmetry angle 62,
9 64 of 60° , 120° and so on, or in other words of
10 $n \cdot 60^\circ$, where n is an integer. Therefore, the cell
11 does not have a rotation symmetry angle of 90° and so
12 the overall material is not orthotropic. Also, the
13 material will be anticlastic.

14
15 Fig. 5 shows an array of cells for the core material
16 20 according to the invention. Each cell comprises
17 a tube 22. The tubes 22 are arranged in a close
18 packed array such that the gap between adjacent
19 tubes is minimised. Since each tube 22 has an
20 infinite rotation symmetry angle, the overall
21 tubular array results in a material which is
22 substantially isotropic and non-anticlastic.

23
24 Fig. 6 shows the tubular array in a curved state.
25 As described above, the planar stress and strain at
26 the neutral axis 14 is zero and so each tube 22
27 retains its circular shape as shown in Fig. 7a. At
28 the inner surface 24, the tubes 22 will be
29 compressed in the direction of the curvature, and
30 the profile of the tubes at this position is shown
31 in exaggerated form in Fig. 7b. At the outer
32 surface 26, the tubes will be elongated in the

1 direction of curvature and the profile of the tubes
2 at this position is shown in Fig. 7c.

3

4 It should be noted that, despite compression and
5 extension of the tubes 22, the profile of the tubes
6 22 when averaged through the thickness of the
7 material 20 will be as found at the neutral axis 14.
8 Also, if there is curvature about an orthogonal
9 axis, this will tend to cause compression and
10 extension in an orthogonal direction, tending to
11 cause the profile of the tubes 22 at any point
12 through the thickness to be as found at the neutral
13 axis 14, although the diameter of the tubes 22 will
14 be reduced at the inner surface 24 and enlarged at
15 the outer surface 26. The tube will in effect be a
16 cone which may even improve the energy absorbing
17 capability of the structure.

18

19 The helmet is formed using a suitable thermoforming
20 process. As shown in Fig. 8, the sandwich panel 12
21 is heated using heaters 70 to a temperature of
22 between 155°C to 160°C, which is above the melt
23 temperature of the adhesive 40.

24

25 The sandwich panel 12 is then transferred to a mould
26 as shown in Fig. 9. The male portion 72 of the
27 mould typically has a rubber contacting face and the
28 female portion 74 is typically constructed from
29 aluminium. The mould is at ambient temperature and
30 the transfer of the panel 12 should be effected
31 quickly, preferably in less than 6 seconds to
32 minimise cooling of the panel 12. The male part 72

1 is then driven towards the female part 74 so that
2 the panel 12 assumes the shape of the mould.

3

4 Since the panel 12 has been heated to above the melt
5 temperature of the adhesive, slippage can take place

6 between the outer skin 30 and the core 20, and
7 between the inner skin 50 and the core 20. Cooling
8 of the panel 12 to a temperature below 50°C ensures
9 that the panel has assumed the curved profile and
10 the adhesive once again bonds each of the skins 30,
11 50 to the core 20. The two parts of the mould can
12 now be separated. The curved panel 12 is shown in
13 Fig. 10.

14

15 Various modifications and improvements can be made
16 without departing from the scope of the present
17 invention. For instance, the tubes of the array may
18 be conical and have a cone angle of any angle.

19

1 CLAIMS

2

3 1. A body protecting device comprising:
4 a first material having an array of energy
5 absorbing cells, wherein each cell comprises a tube.

6

7 2. The body protecting device of Claim 1, wherein
8 the device comprises a safety helmet.

9

10 3. The body protecting device of Claim 1, wherein
11 the device comprises a safety pad.

12

13 4. The body protecting device of any preceding
14 claim, wherein each tube has a diameter of between 2
15 and 8 mm.

16

17 5. The body protecting device of any preceding
18 claim, wherein the first material has, or can deform
19 to, a large curvature.

20

21 6. The body protecting device of any preceding
22 claim, wherein the first material comprises one of
23 polycarbonate, polypropylene, polyetherimide,
24 polyethersulphone or polyphenylsulphone.

25

26 7. A liner for a body protecting device, the liner
27 comprising:

28 a first material having an array of energy
29 absorbing cells, wherein each cell comprises a tube.

30

31 8. A body protecting device comprising:

1 a first material bonded to a second material
2 using an adhesive, wherein the adhesive has a melt
3 temperature which is lower than the melt temperature
4 of the first and second material.

5

6 9. The body protecting device of Claim 8, wherein
7 the first and second materials are in a softened
8 state at the melt temperature of the adhesive.

9

10 10. The body protecting device of Claim 8 or 9,
11 wherein the first material is one of a
12 polycarbonate, polypropylene, polyetherimide,
13 polyethersulphone or polyphenylsulphone material.

14

15 11. The body protecting device of any of Claims 8
16 to 10, wherein the second material is a plastics
17 material.

18

19 12. The body protecting device of Claim 11, wherein
20 the second material is a fibre reinforced plastics
21 material.

22

23 13. The body protecting device of any of Claims 8
24 to 12, wherein the adhesive is a thermoplastic.

25

26 14. The body protecting device of Claim 13, wherein
27 the adhesive is a polyester based material.

28

29 15. The body protecting device of any of Claims 8
30 to 14, wherein the melt temperature of the adhesive
31 is less than 180°C.

32

1 16. The body protecting device of Claim 15; wherein
2 the melt temperature of the adhesive is between
3 120°C and 140°C.
4

5 17. The body protecting device of Claim 16, wherein
6 the body protecting device is heated during forming
7 to between 155°C and 160°C.
8

9 18. The body protecting device of any of Claims 8
10 to 17, further comprising a third material, wherein
11 the first material interposes the second and third
12 materials, and wherein the first material is bonded
13 to the third material using the adhesive.
14

15 19. The body protecting device of any of Claims 8
16 to 18, wherein the first material has an array of
17 energy absorbing cells, each cell comprising a tube.
18

19 20. A method of forming a body protecting device
20 comprising:

21 bonding a first material to a second material
22 using an adhesive, wherein the adhesive has a melt
23 temperature which is lower than the melt temperature
24 of the first and second material.
25

26 21. The method of Claim 20, including selecting
27 first and second materials which are in a softened
28 state at the melt temperature of the first material.
29

30 22. The method of Claim 20 or 21, including heating
31 the body protecting device during forming to between
32 155°C and 160°C.

1

2 23. The method of any of Claims 20 to 22, including
3 bonding the first material to a third material using
4 the adhesive.

5

6 24. The method of any of Claims 20 to 23, wherein
7 the first material has an array of energy absorbing
8 cells, each cell comprising a tube.

9

10

1 **ABSTRACT**

2

3 A body protecting device, such as a safety helmet or

4 safety pad, comprises a first material having an

5 array of energy absorbing cells, wherein each cell

6 comprises a tube.

7

8

9

10

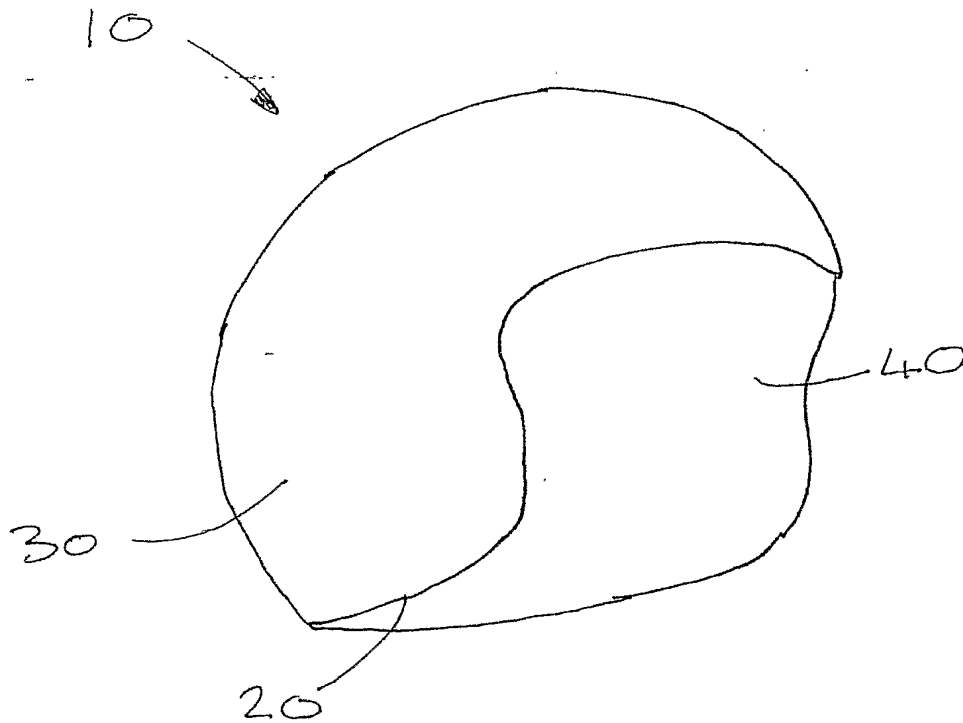


Fig 1



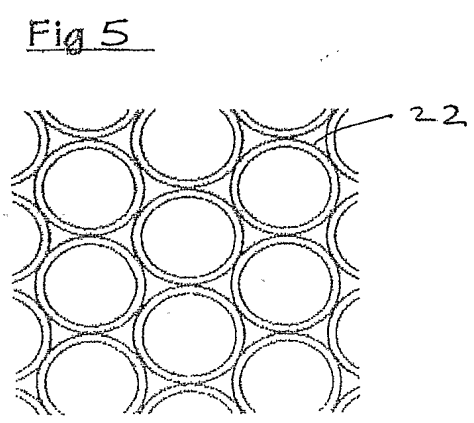
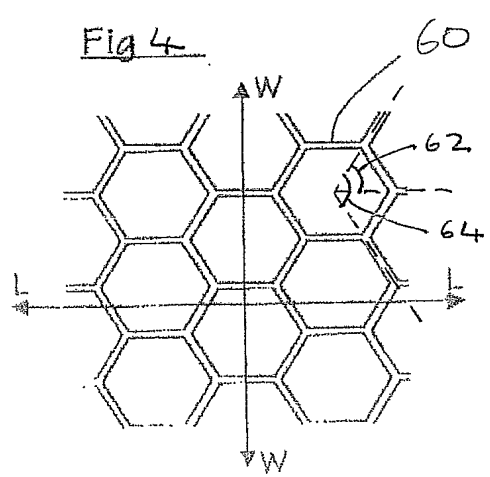
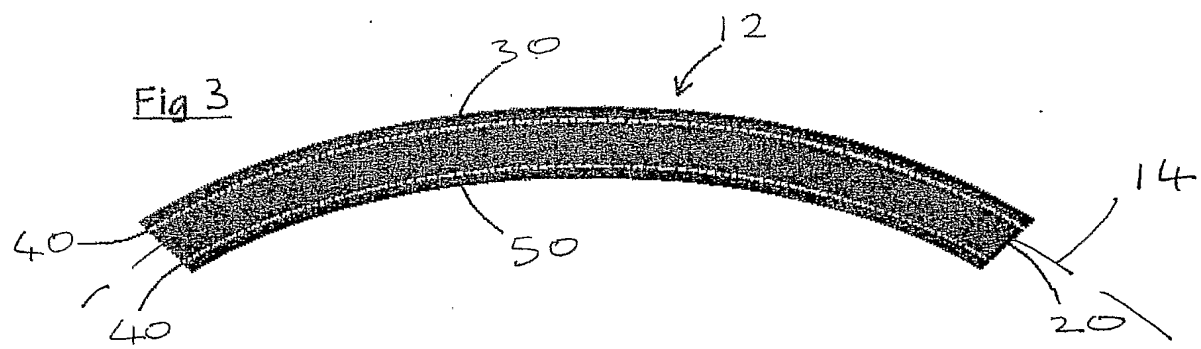
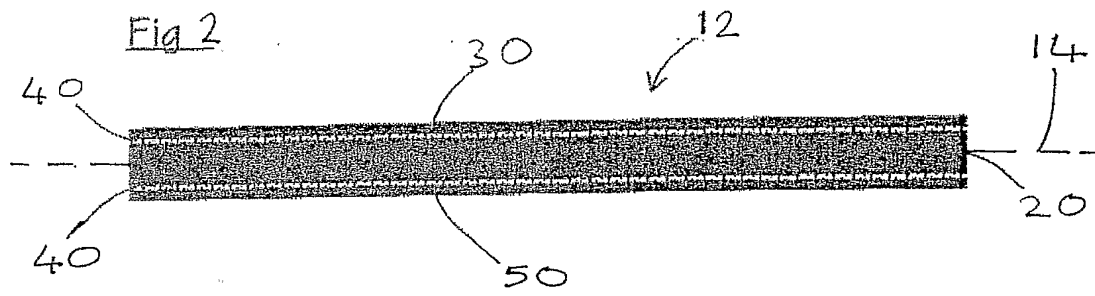




Fig 6

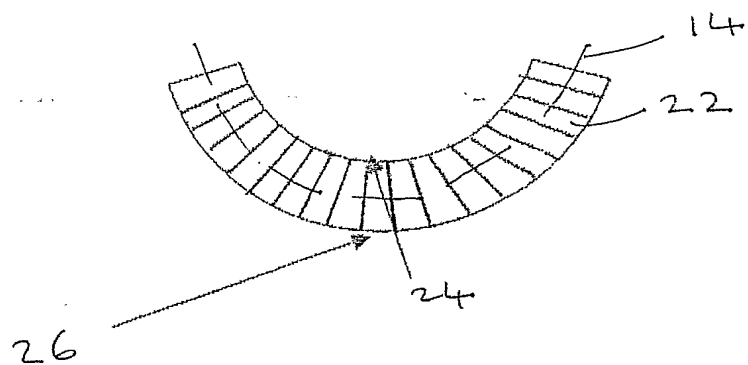


Fig 7a

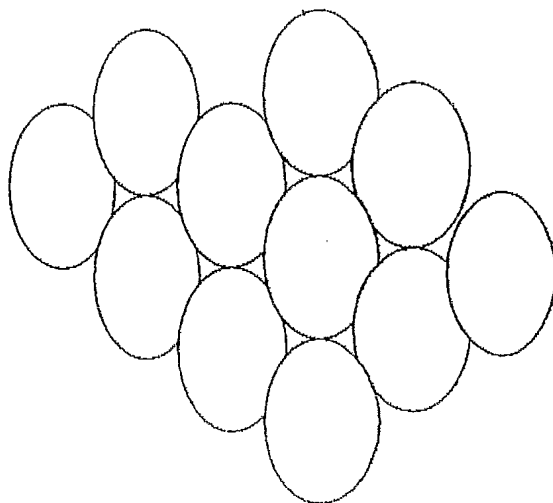
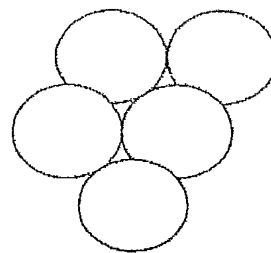


Fig 7b

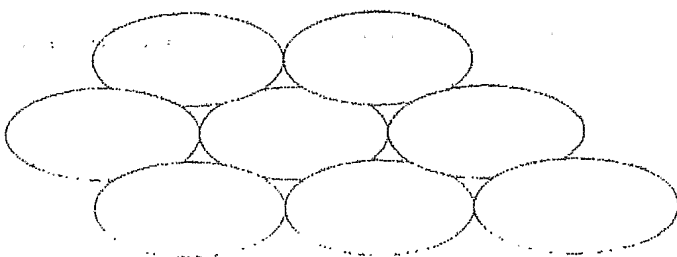


Fig 7c



Fig 8

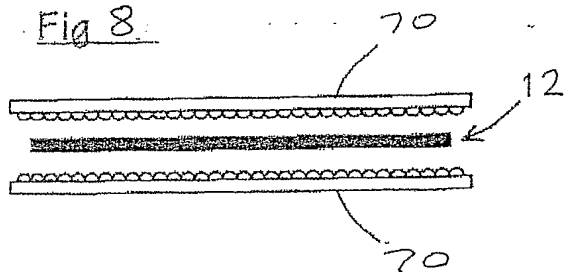


Fig 9

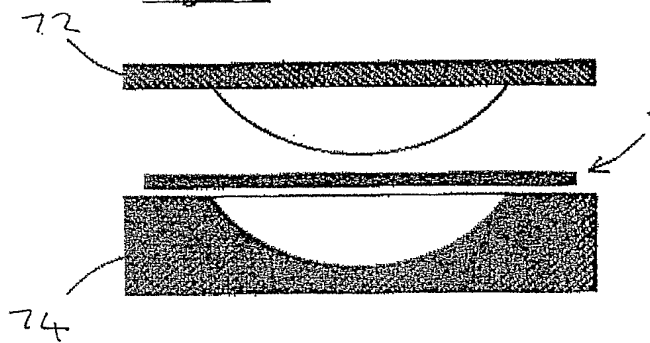
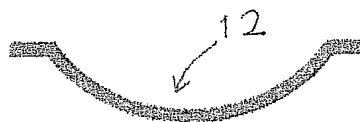


Fig 10



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